

# CosmicSIG Status and Plans

**Cosmic Ray *Science Interest Group***

PhysPAG Town Hall at AAS, January 5, 2014

# CosmicSIG Activities

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- ▶ Committee formed April 2013

- ▶ John Mitchel (GSFC), Igor Moskalenko (Stanford U), Angela Olinto (U Chicago) Chair, Eun-Suk Seo (U Maryland)

- ▶ Goals of CosmicSIG

- ▶ Provide an assessment to NASA HQ and the PCOS program office of the status and the **current and future** needs of the **cosmic-ray astrophysics** community.
  - ▶ Act as a **focal point** and forum for the cosmic ray community.

- ▶ White Paper with Cosmic Ray vision for the next decade(s)

- ▶ Gather input from Community
  - ▶ Survey current and future projects and missions and their science goals and coverage
  - ▶ Survey technology development needs for future progress in the field





**National Aeronautics and Space Administration**  
Goddard Space Flight Center

- Goddard Space Flight Center
- Sciences and Exploration Division
- Astrophysics Science Division

## Physics of the Cosmos

[Overview](#)[Projects](#)[Science](#)[Technology](#)[Studies](#)[Program Office](#)[Education](#)

### Links

- PhysPAG

### Science Interest Groups (SIGS)

- CosmicSIG (Cosmic Ray SIG)
- IPSIG (Inflation Probe SIG)
- GWSIG (Gravitational Wave SIG)
- XRSIG (X-ray SIG)
- GammaSIG (Gamma ray SIG)
- TechSAG (Technology, no longer active as of January 2012)

### Cosmic Ray SIG

Angela Olinto, Chair — [olinto@kicp.uchicago.edu](mailto:olinto@kicp.uchicago.edu)

The goals of the Cosmic Ray Science Interest Group (CosmicSIG) are to provide quantitative metrics and assessments to NASA in regard to current and future needs of the cosmic-ray astrophysics community and to act as a focal point and forum for the cosmic ray community.

The CosmicSIG is composed of John Mitchel (GSFC), Igor Moskalenko (Stanford U), Angela V. Olinto (U Chicago) Chair, Eun-Suk Seo (U Maryland). CosmicSIG will work towards producing a white paper covering:

- the major open science questions
- a brief survey of the current and planned, US and International, space and ground-based projects & their energy coverage (from about  $10^8$  eV to  $10^{20}$  eV), sky coverage, and particle type coverage (electrons, positrons, nucleons, anti-nucleons, nuclei, anti-nuclei, neutrinos, and new particles)
- a survey of the state-of-the-art capabilities, the next generation technology needs, and potential science return from new technologies and capabilities
- a vision for the future of cosmic ray science in space

The CosmicSIG is open to all members of the community.

If you are interested in contributing to the work of the CosmicSIG, please subscribe using the link below. For other inquiries, e-mail Angela Olinto, chair of the CosmicSIG, at [olinto@uchicago.edu](mailto:olinto@uchicago.edu)

### CosmicSIG Mailing List

Subscribe to the [CosmicSIG mailing list](#).

### Program News

**6 Dec 2013**

PhysPAG Executive Committee Selections, Memo from NASA Headquarters December 2013  
• [\[PDF\]](#)

**1 Nov 2013**

PCOS Program Annual Technology Report for 2013 is released. • [\[PDF\]](#)

**20 Sept 2013**

Announcing: XAP STDY Membership • [Details](#)

### Project News

**Chandra News**

**24 Oct 2013**

NASA's Great Observatories Begin Deepest Ever Probe of the Universe • [Details](#)

**Fermi News**

**21 Aug 2013**

NASA's Fermi Celebrates Five Years in Space, Enters Extended Mission • [Details](#)

**Planck News**

**23 Oct 2013**

Last Command Sent to ESA's Planck Space Telescope  
• [Details](#)

# CosmicSIG Activities

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- ▶ Gathering input from Community
  - ▶ “June 2012”: open meeting at CR2012 requesting input from the community
  - ▶ Teleconferences and email input for further information gathering.
  - ▶ ICRC 2013
- ▶ Fall 2013: compile previous white papers (Astro 2010 prep to NWNH, *Enduring Quests Daring Visions*,...).
- ▶ Winter 2014: draft white paper
- ▶ April 2014: present white paper draft at APS meeting
- ▶ Fall 2014: deliver white paper to PhysPAG (+ NAC)



# NASA Astrophys Roadmap



December 20, 2013


















	Near-Term	Formative	Visionary
Gravitational Waves		 Gravitational Wave Surveyor	 Gravitational Wave Mapper
Cosmic rays	 JEM-EUSO		
Radio			 Cosmic Dawn Mapper
Microwaves		 CMB Polarization Surveyor	
Infrared	 JWST	 Far IR Surveyor	
	 WFIRST-AFTA	 LUVOIR Surveyor	 ExoEarth Mapper
	 Euclid		
Optical	 TESS	 Gaia	
Ultraviolet			
X-rays	 NICER	 Astro-H	 Xray Surveyor
Gamma rays			 Black Hole Mapper

Figure 1.2 Chart of the missions currently planned for launch during the Near-Term Era and of the notional missions of this roadmap for the Formative and Visionary Eras.

# NASA Astrophys Roadmap



December 20, 2013

## ENDURING QUESTS

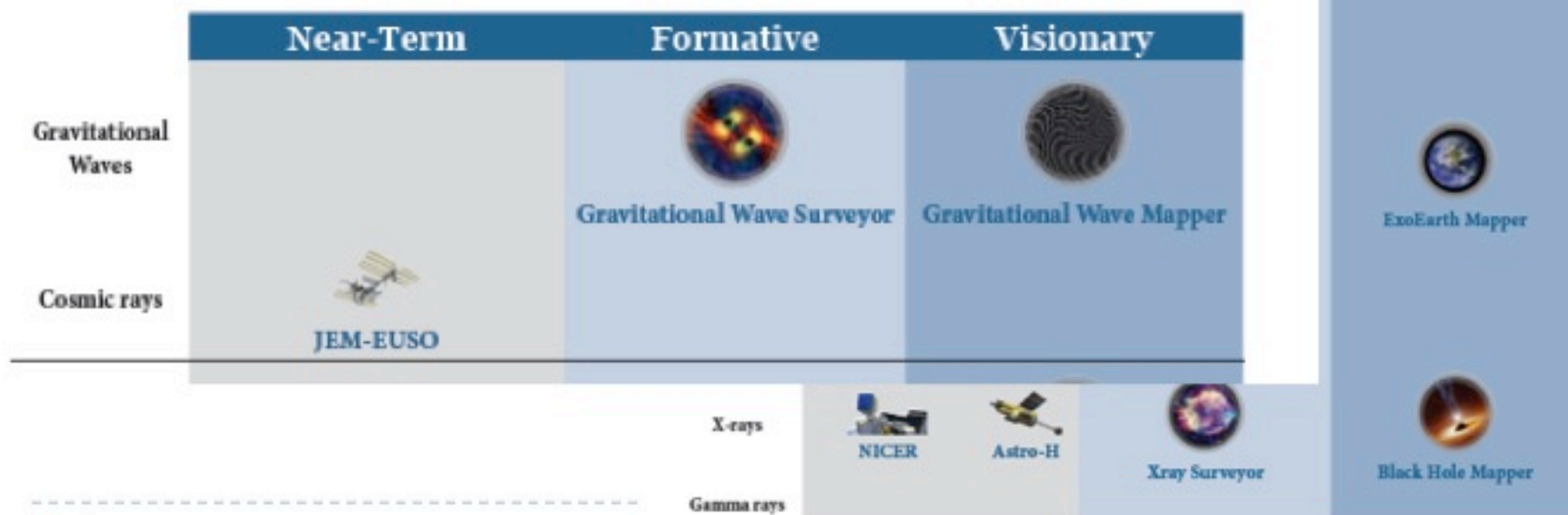


Figure 1.2 Chart of the missions currently planned for launch during the Near-Term Era and of the notional missions of this roadmap for the Formative and Visionary Eras.



## *Particle Accelerators*

THERE is yet another, less apparent component of galaxies: high-energy particles (cosmic rays). A century ago, Victor Hess discovered via high-altitude balloons a background of high-energy charged particles, which we now know pervades the ISM, providing about a third of its energy density. This dynamically important gas of particles requires efficient acceleration, which is now believed to take place in the strong shock waves of supernova remnants. Only recently did gamma-ray observations in the GeV regime (from space) and the TeV regime (from the ground) yield convincing data supporting this paradigm. About half a dozen stars are born every year in the Milky Way; those with sufficiently high mass ultimately end their lives as supernovae, resulting in a few supernova explosions per century. Due to their large energy per explosion, this rate is sufficient to maintain a significant fraction of the ISM in a hot and ionized state, emitting characteristic line radiation in the ultraviolet and X-ray bands. The study of galactic cosmic rays with space based detectors (e.g., Fermi, AMS) and ground-based facilities, such as the Auger array in Argentina (and indirectly through ground-based observations of very high-energy gamma rays), can be advanced with dedicated detectors on the International Space Station such as JEM-EUSO, which will utilize Earth's atmosphere as a particle detector. The study of cosmic ray particle acceleration is an important physics question in its own right, but this high-energy particle component of any actively star-forming galaxy is also responsible for the creation of some crucial elements (lithium, beryllium, and boron). It bathes the galaxy in a diffuse glow of high-energy gamma rays, which represents a significant fraction of its total energy output; the presence of the cosmic ray component can even play a substantial role in the self-regulation of the star-formation rate. The motion of the Sun-Earth system in the galactic potential causes changes to the cosmic ray environment on timescales on the order of 100 million years, which could potentially be linked to extinction cycles on Earth.

# Cosmic Rays 2013 Highlights - Space

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# The Great Voyage

1977 to now and onwards...

Voyager 1 and 2 in 2012 Voyager  
'leave' the Heliosphere in the

Moving at 17.26 km/s

## Heliosphere

## Bow Shock?

## Voyager 1

## Voyager 2

Cheliosiphon

Termination Shock

Sun

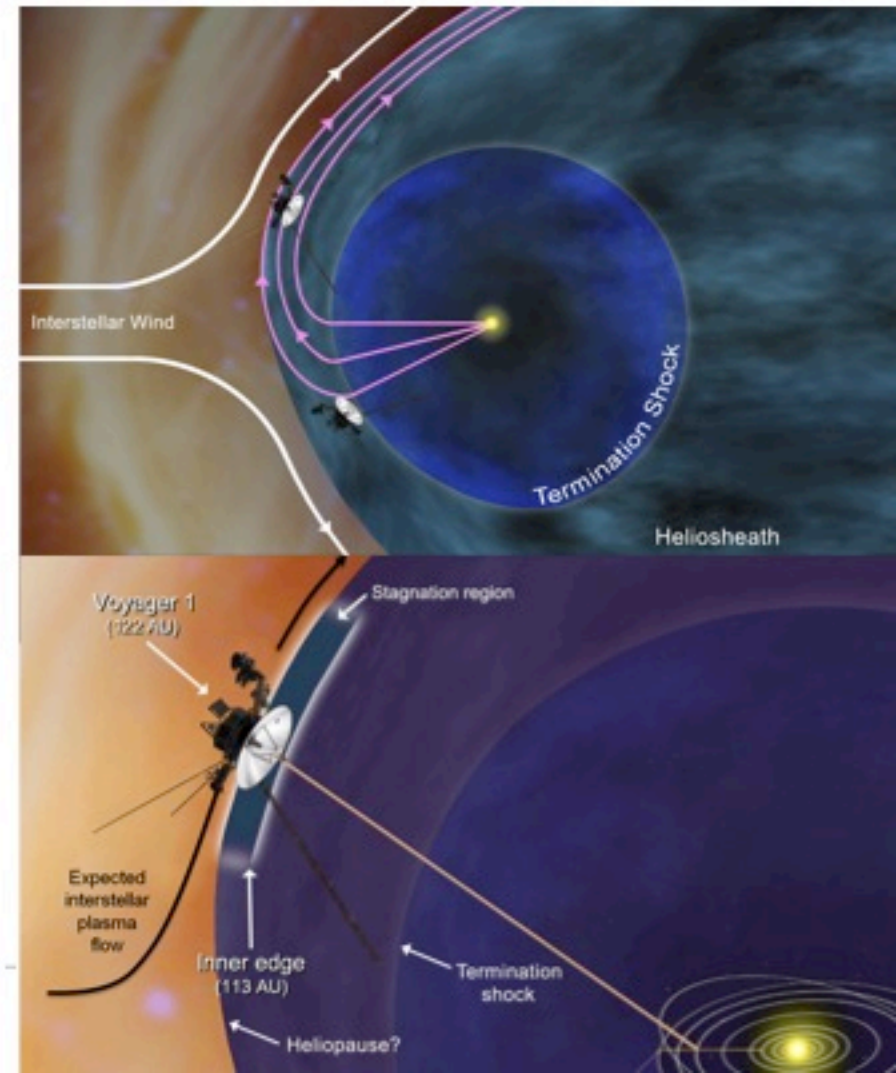
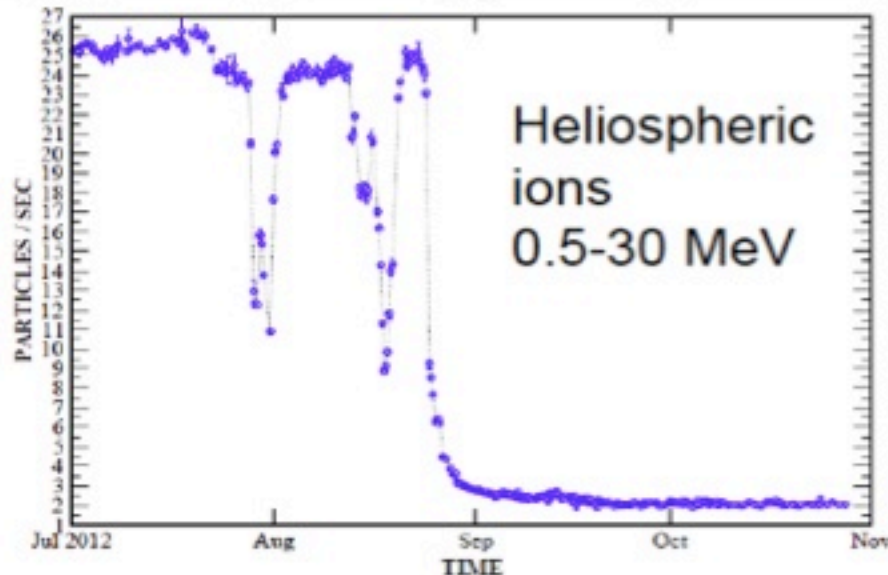
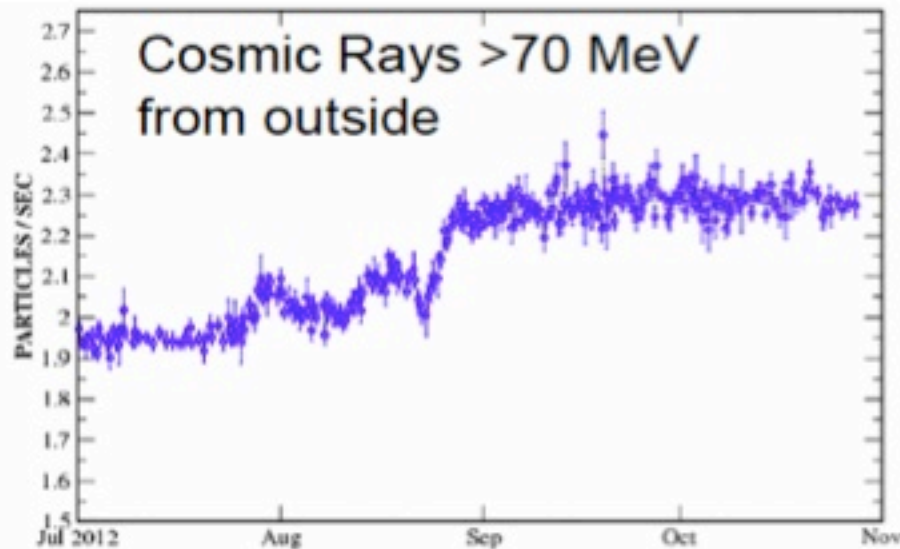
Heliopause



## Ed Stone & Voyager

# Cosmic Rays Recent Highlights

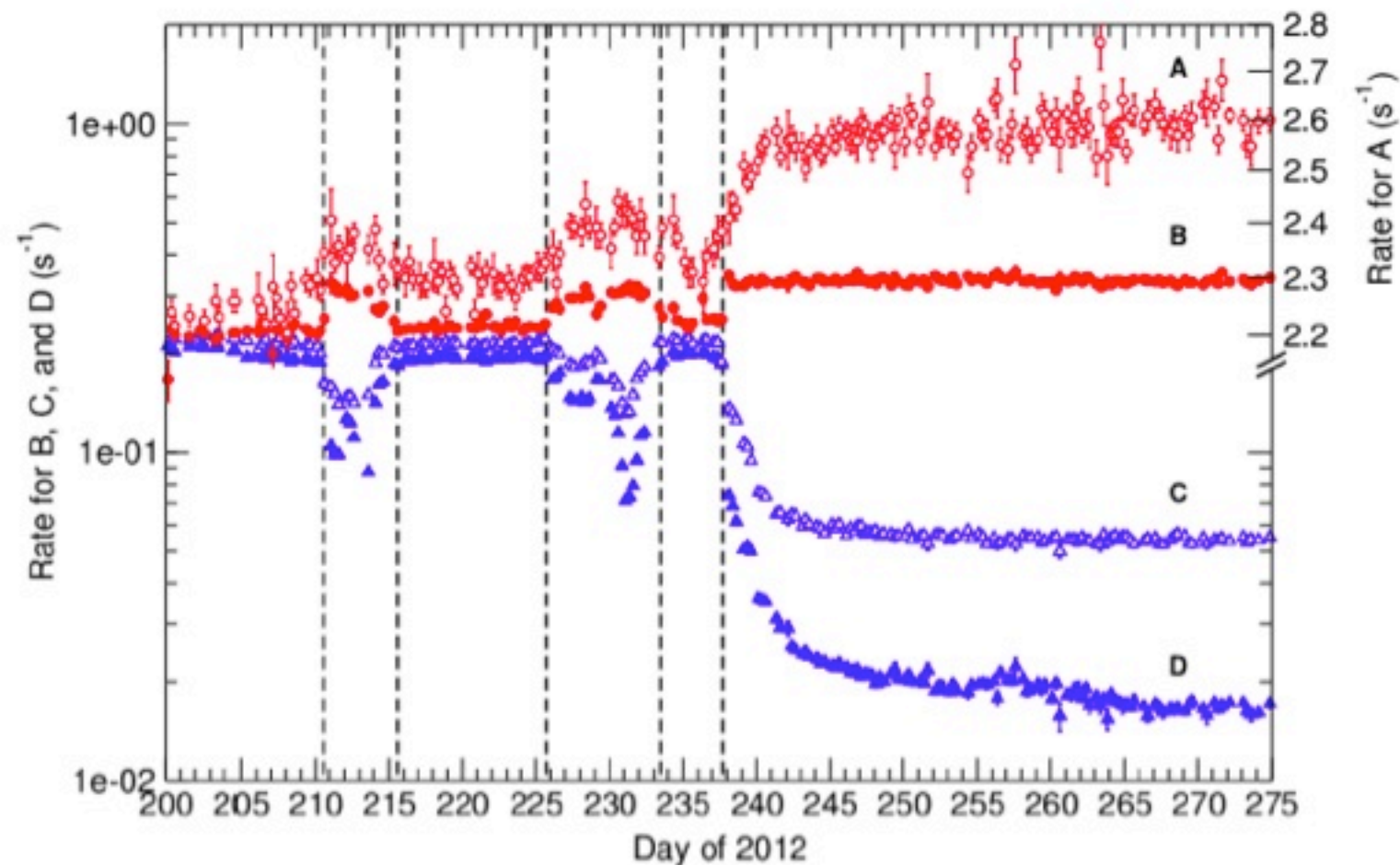
## ► Voyager I reaches Interstellar Space (Aug/Sep 2012)





Galactic CRs  $\uparrow$

Heliospheric CRs  $\downarrow$



From outside:

GCR protons  
>70 MeV

GCR electrons  
7 to ~100 MeV

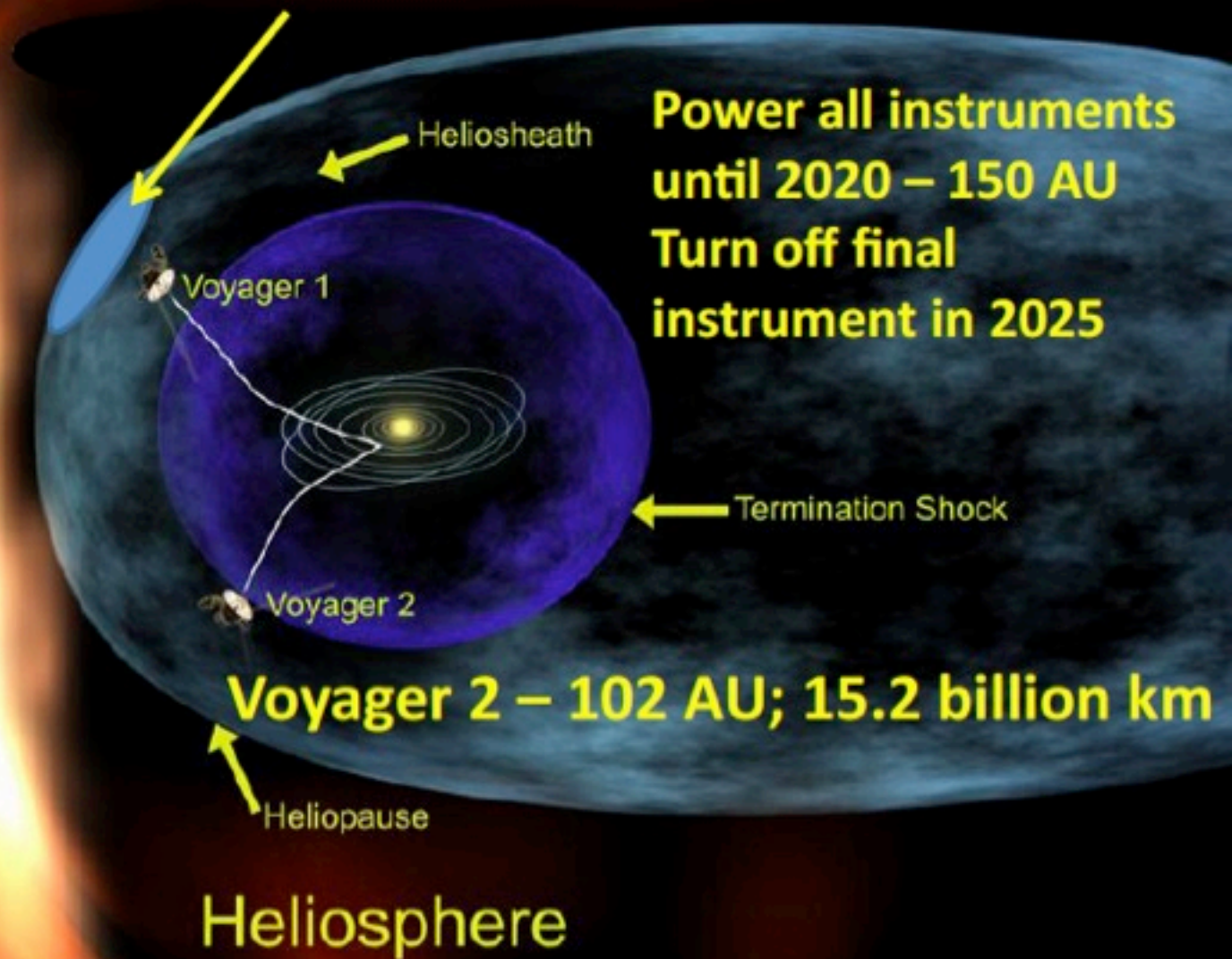
From inside:

ACR protons  
7 to 60 MeV

TSPs  
0.5 to 30 MeV



**Voyager 1 – 124 AU; 18.6 billion km**



# Cosmic Rays 2013 Highlights (Mar'13)

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- ▶ AMS (Alpha Magnetic Spectrometer) on the ISS announces first results

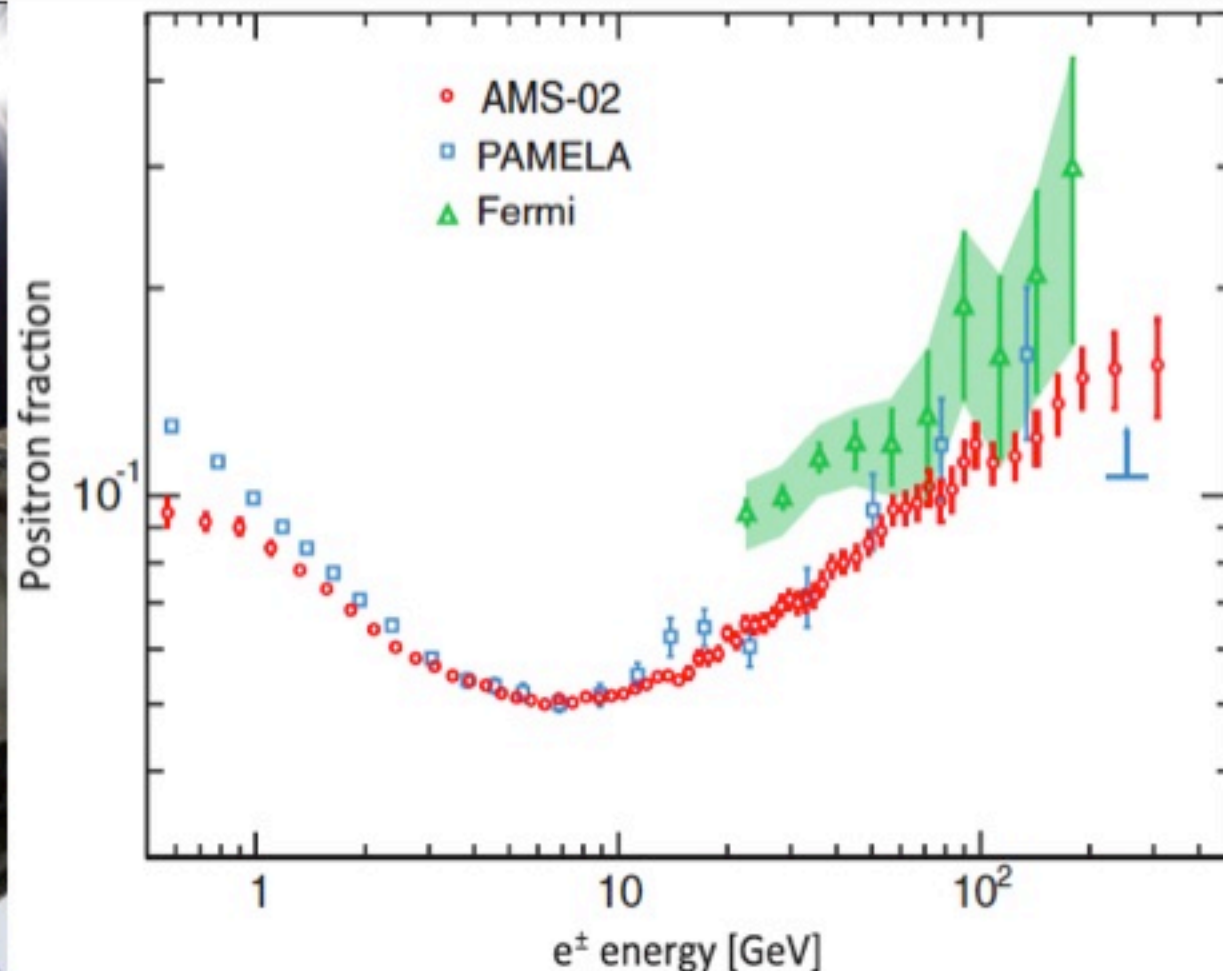




# Cosmic Rays 2013 Highlights (Mar'13)

- AMS (Alpha Magnetic Spectrometer) on the ISS announces first results

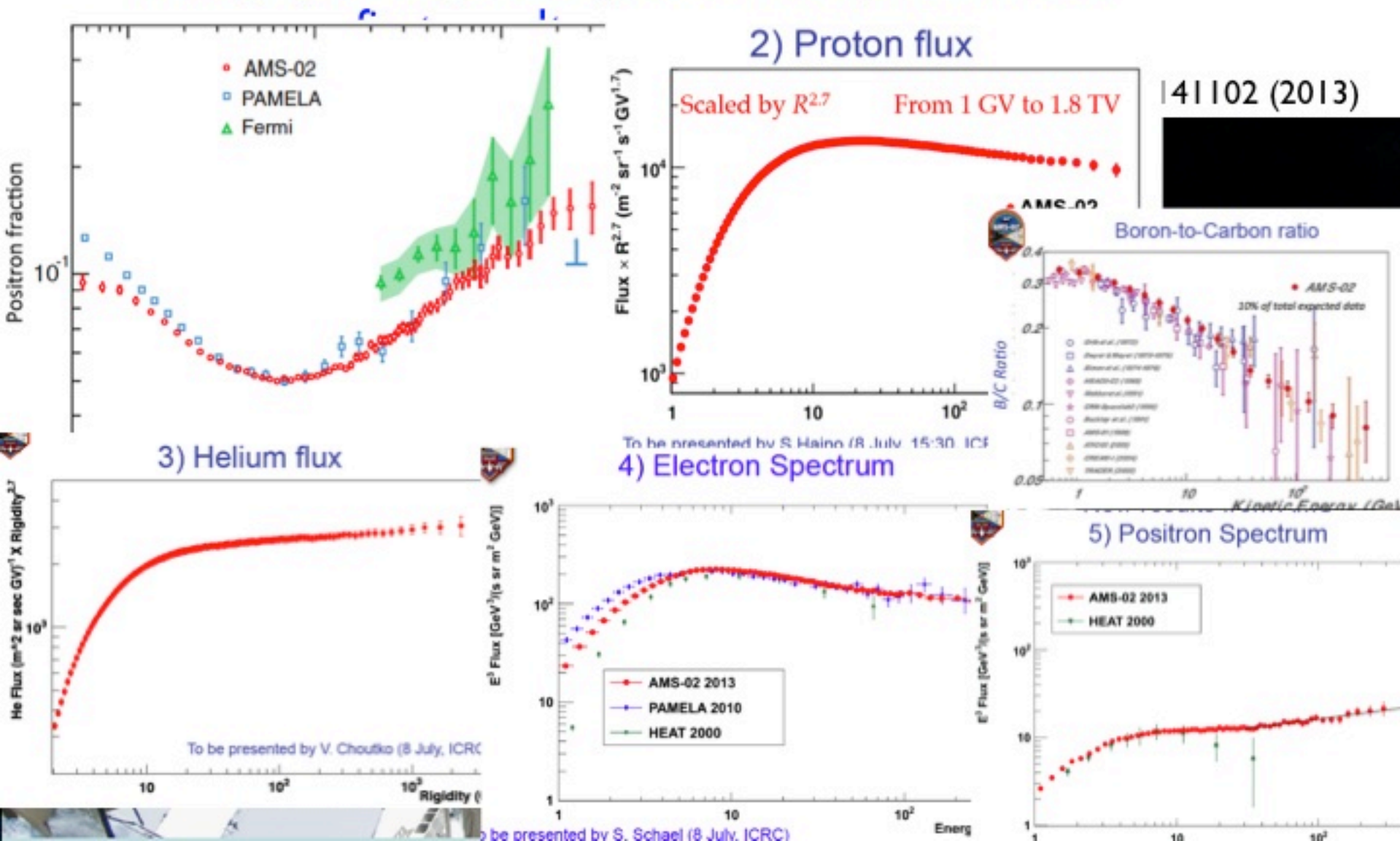
PRL 110, 141102 (2013)





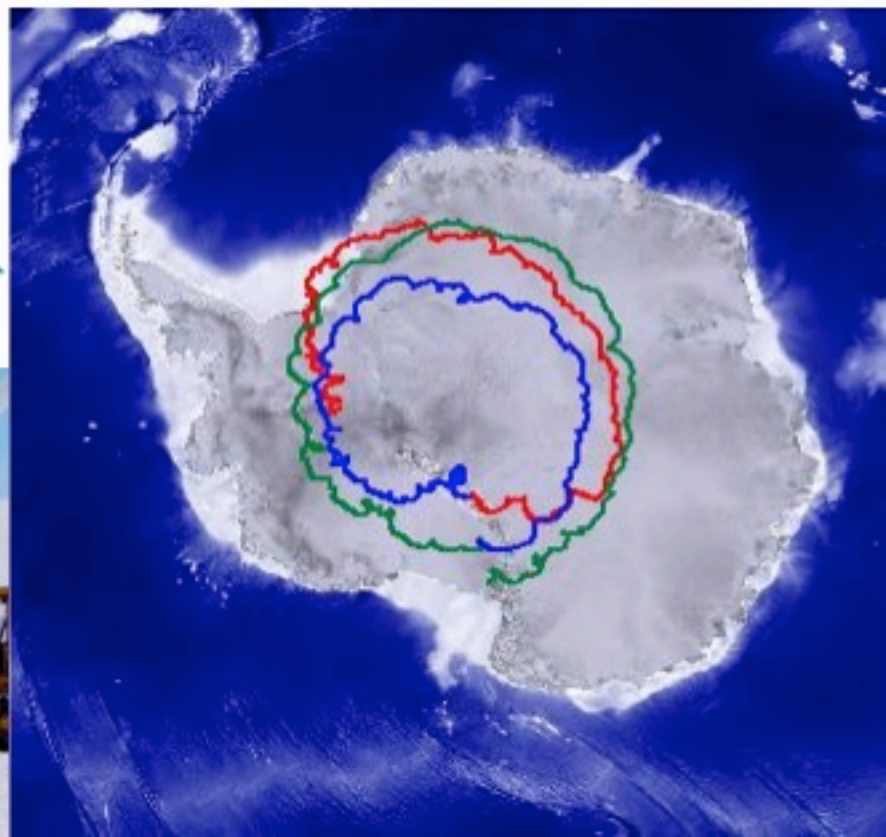
# Cosmic Rays 2013 Highlights (Jul'13)

## AMS (Alpha Magnetic Spectrometer) on the ISS



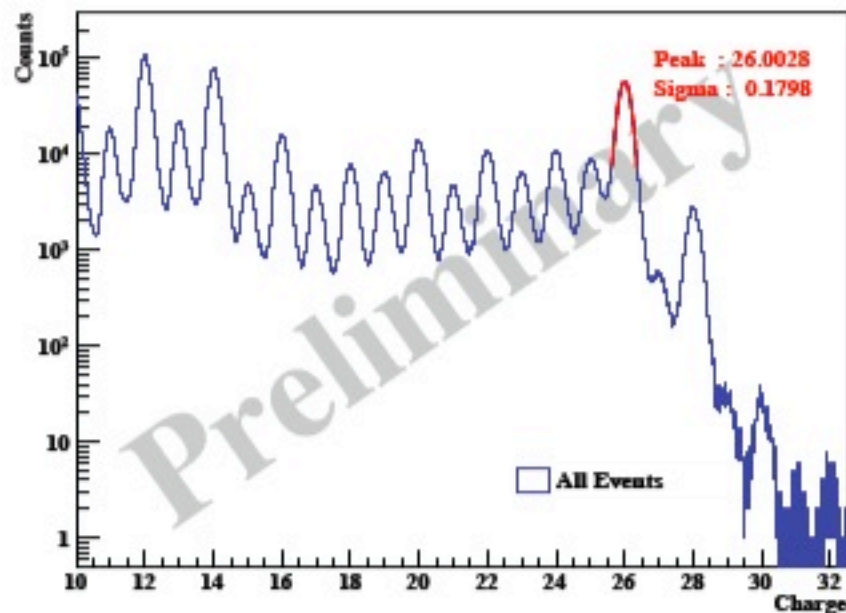
# Cosmic Rays 2013 Highlights (Feb' 13)

- ▶ Super-TIGER (Trans-Iron Galactic Element Recorder) breaks flight duration record: 55 days at 127,000 feet
  - ▶ Increase on UltraHeavy Nuclei data by 1 o.o.m. to study composition and origin of Galactic Cosmic Rays

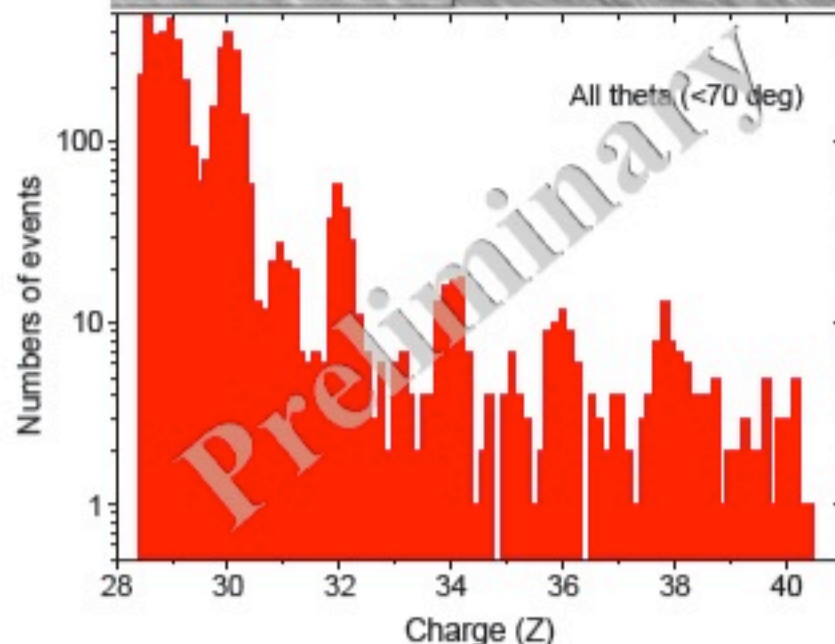
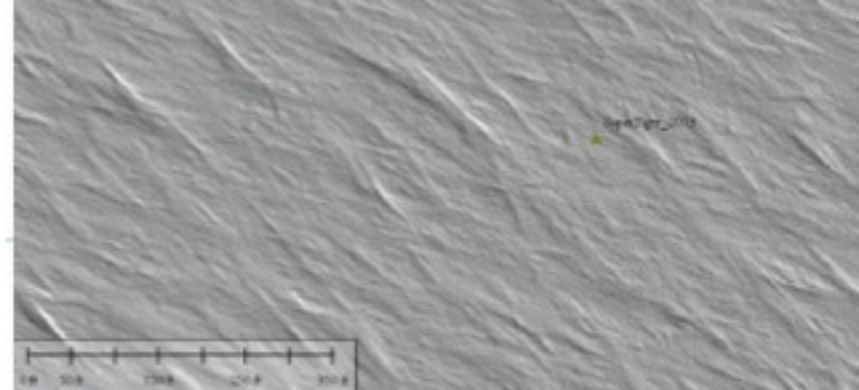




# Super-TIGER Update



- All events
- $\sigma_Z = 0.18$  charge units resolution at Fe (compared to  $\sim 0.23$  for TIGER)



- Events w  $Z > 30$ , analysis underway
- Expect improved resolution w better models of velocity and charge-dependent scintillator saturation

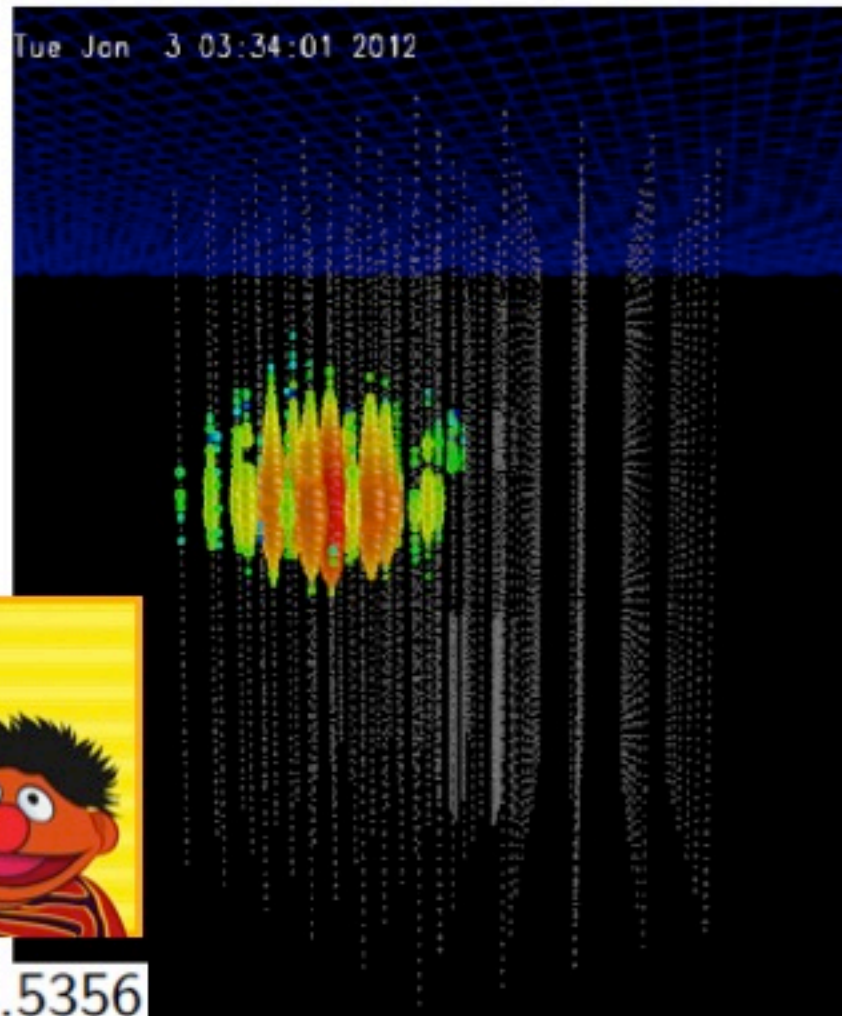
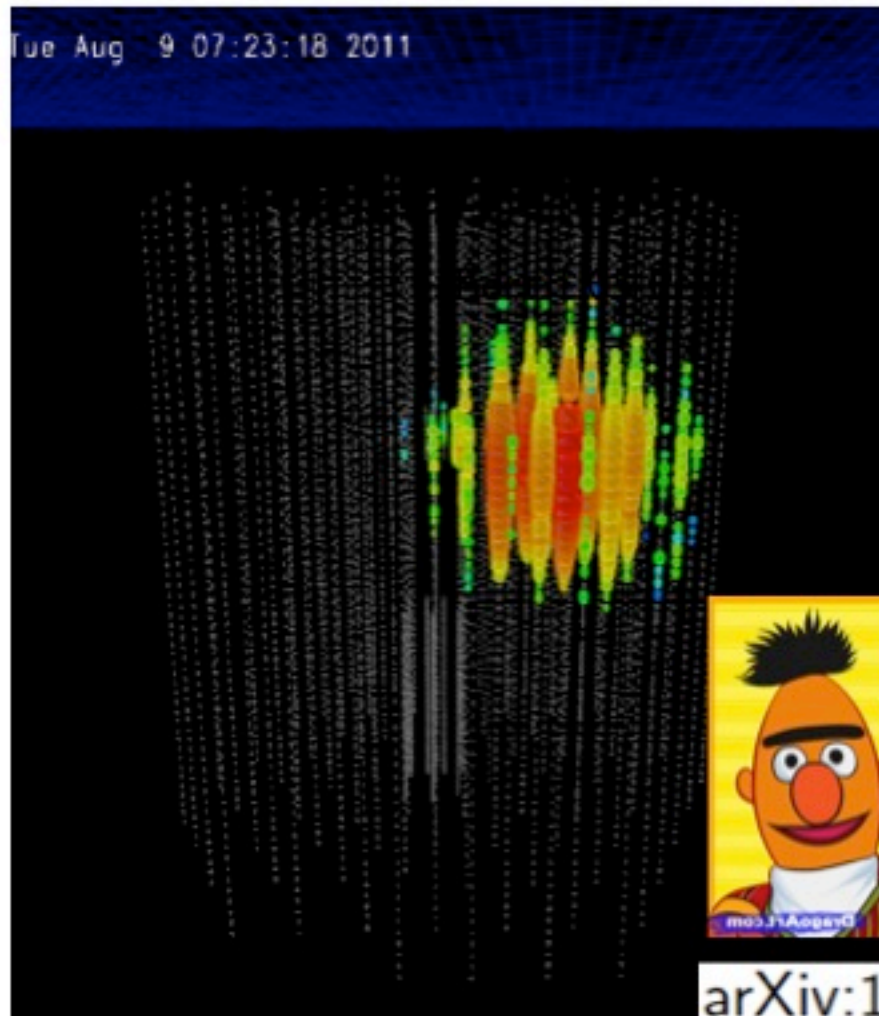


# Cosmic Rays 2013 Highlights - Ground

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# Neutrino Astronomy Begins

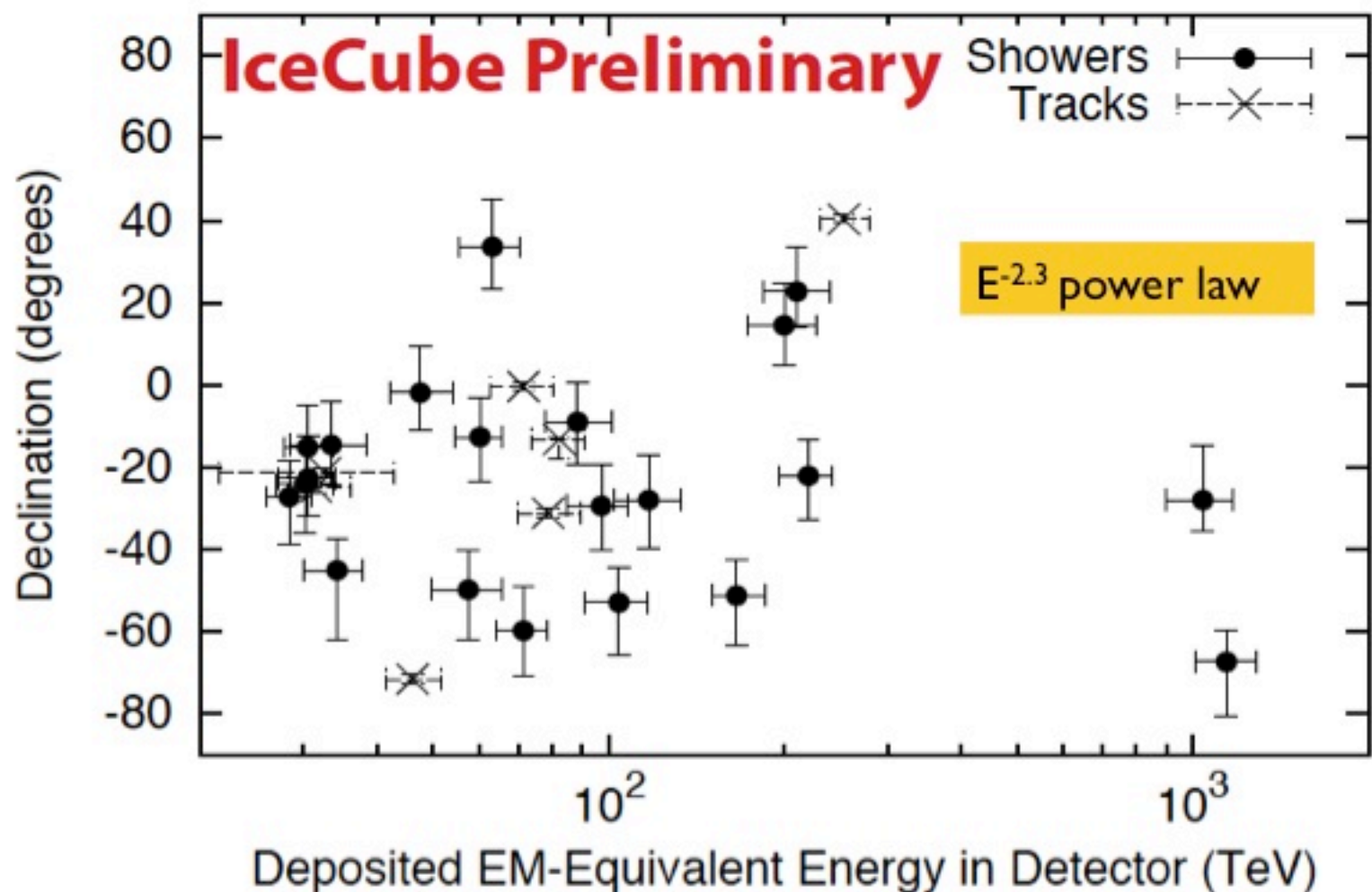
- ▶ PeV neutrinos first observed by **IceCube** (Apr'13)



arXiv:1304.5356

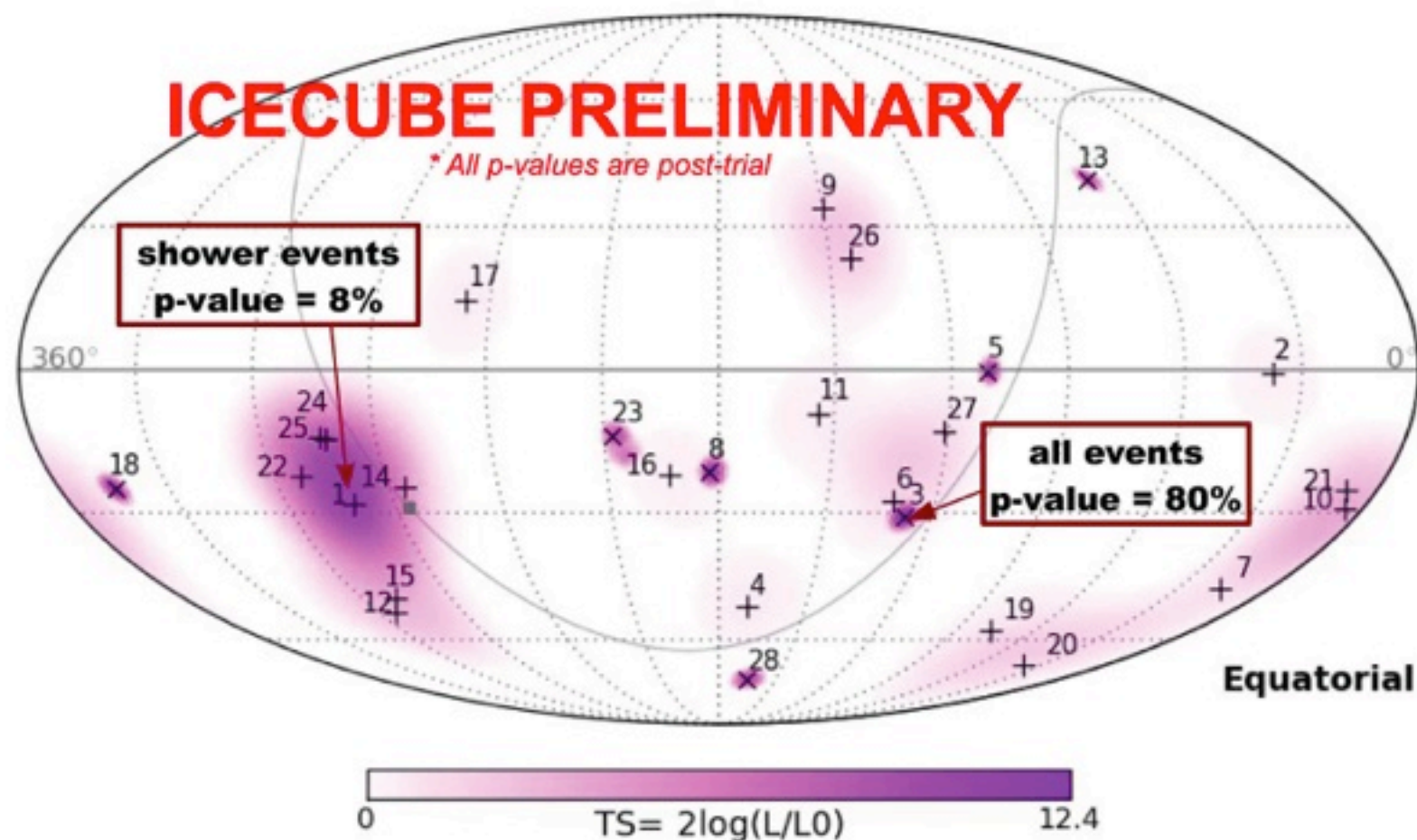


## Results of Contained Vertex Event Search ( $4.3\sigma$ )



28 events (7 with visible muons, 21 without) on background of  $10.6^{+4.5}_{-3.9}$  ( $12.1 \pm 3.4$  with reference charm model)

# Skymap: No Significant Clustering

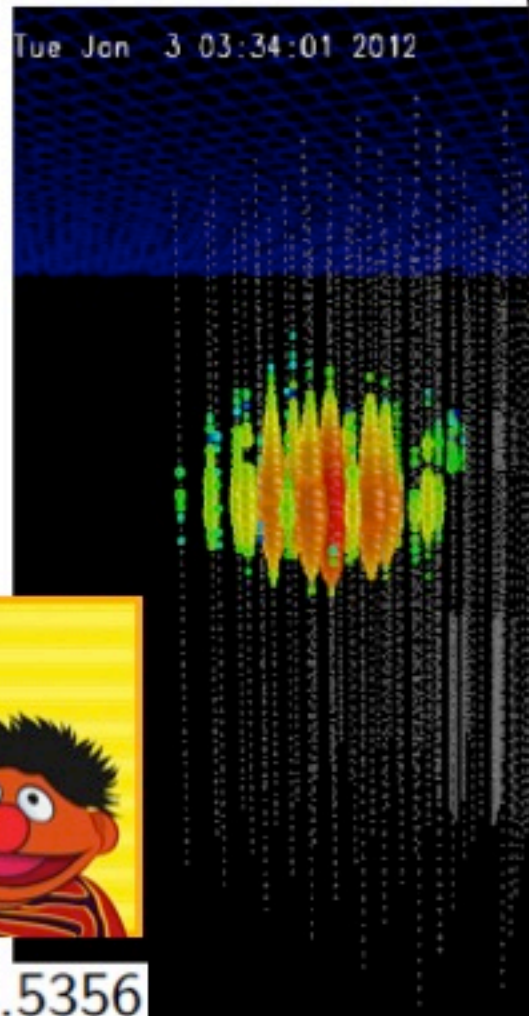
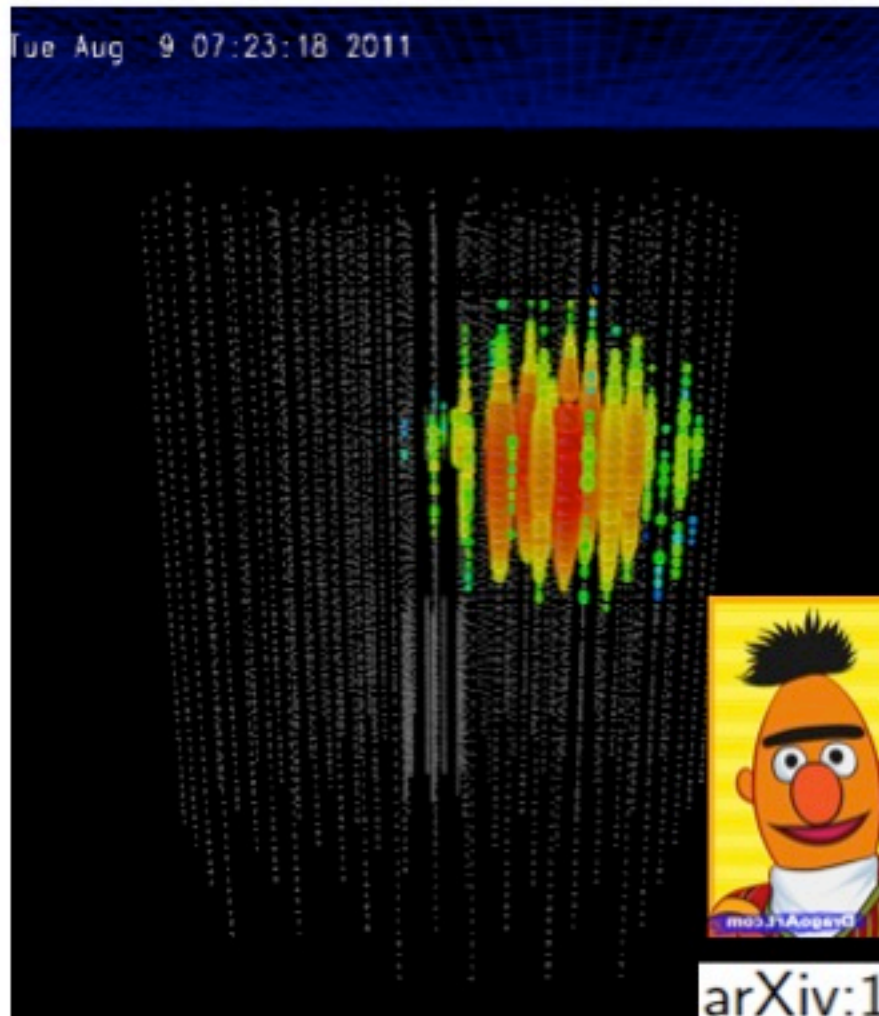


See: talk by Naoko Kurahashi Neilson



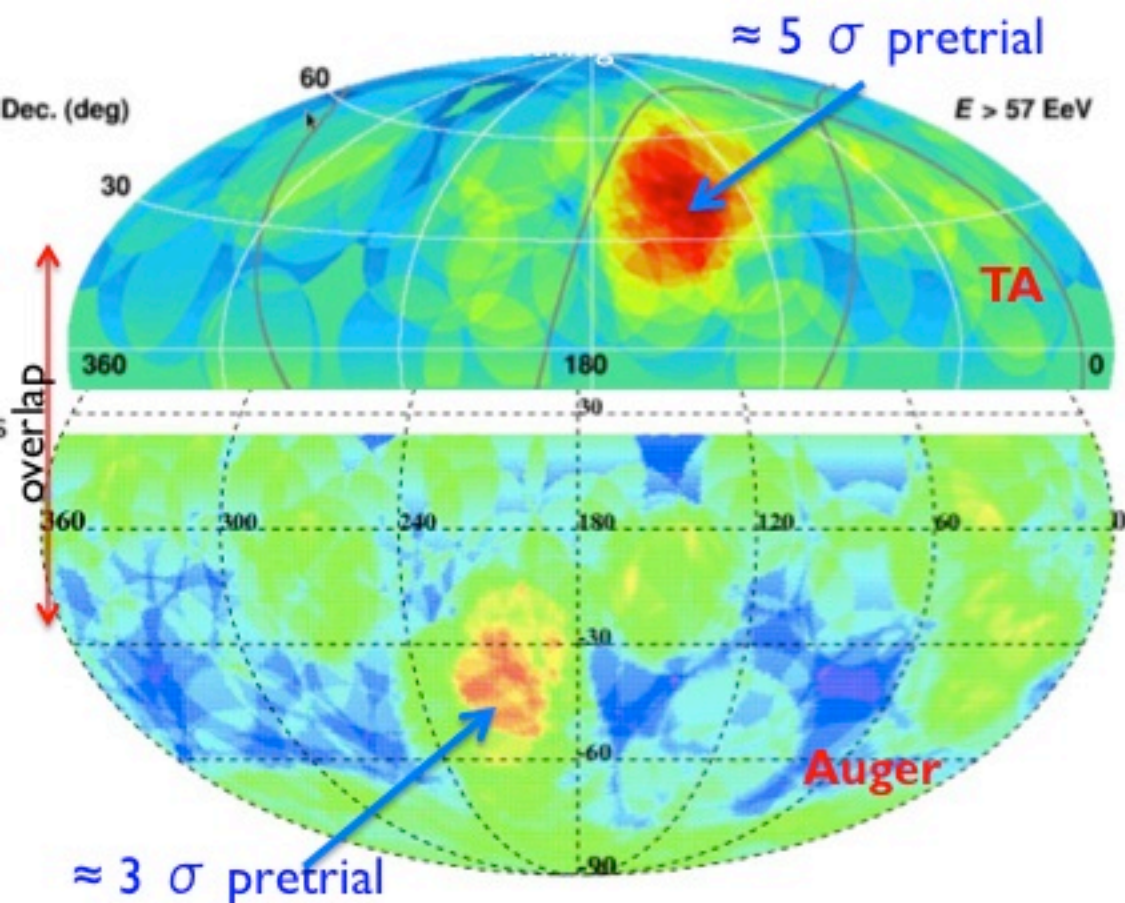
# Neutrino Astronomy Begins

- ▶ PeV neutrinos first observed by **IceCube** (Apr'13)

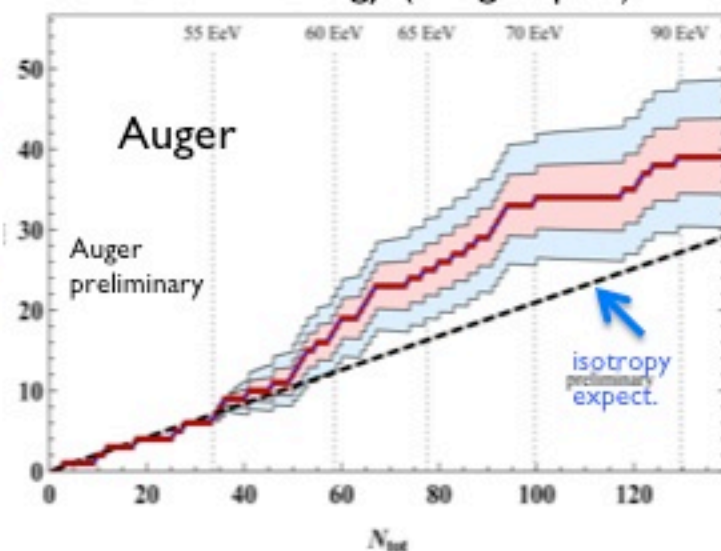


# UHECR Anisotropy Hints >60 EeV

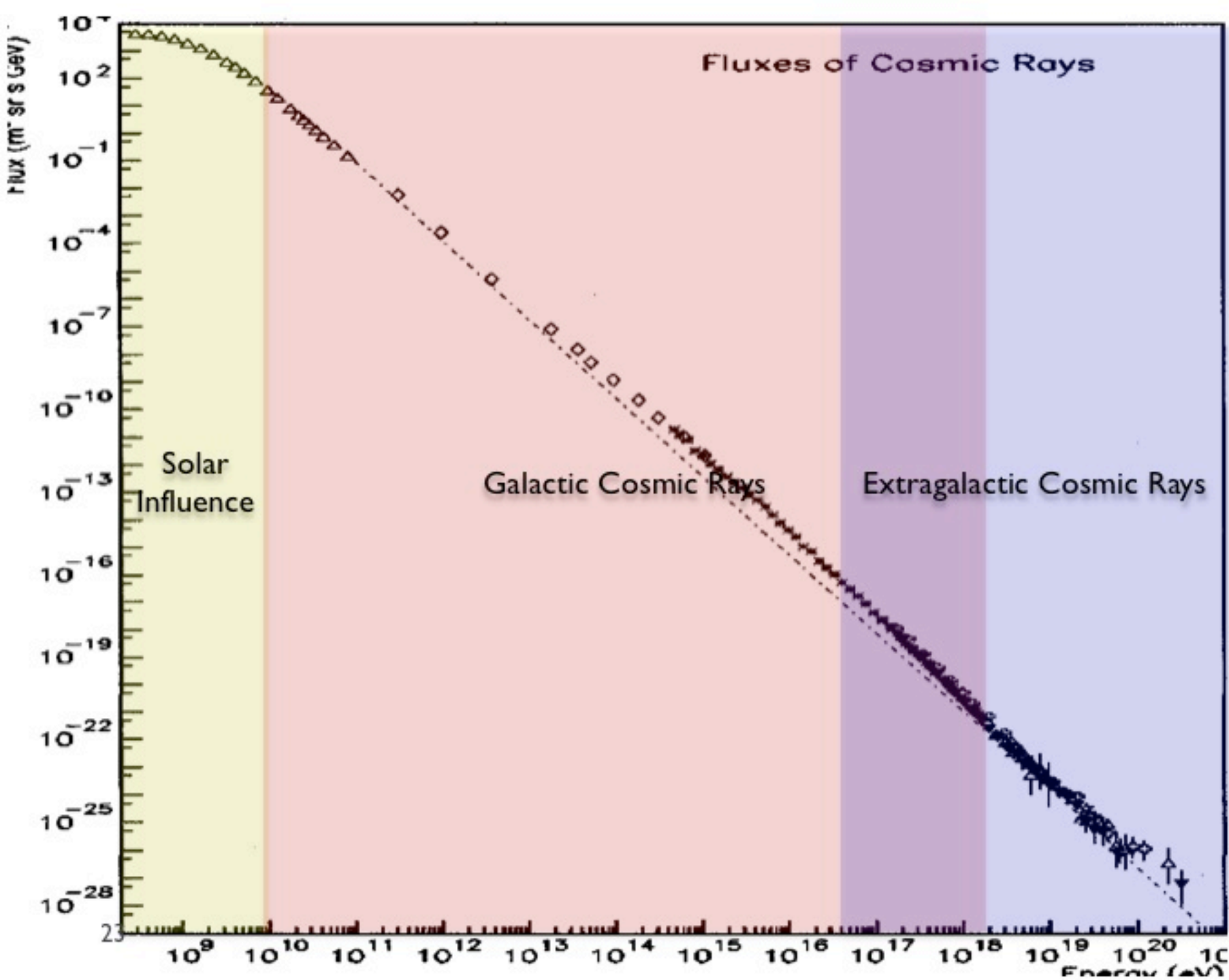
Statistically limited evidence for Cosmic Ray Anisotropy above  $5.7 \times 10^{19}$  eV in the North and South



# of events correlating with AGN, ordered in energy (integral plot)







# Open Questions in CR Science

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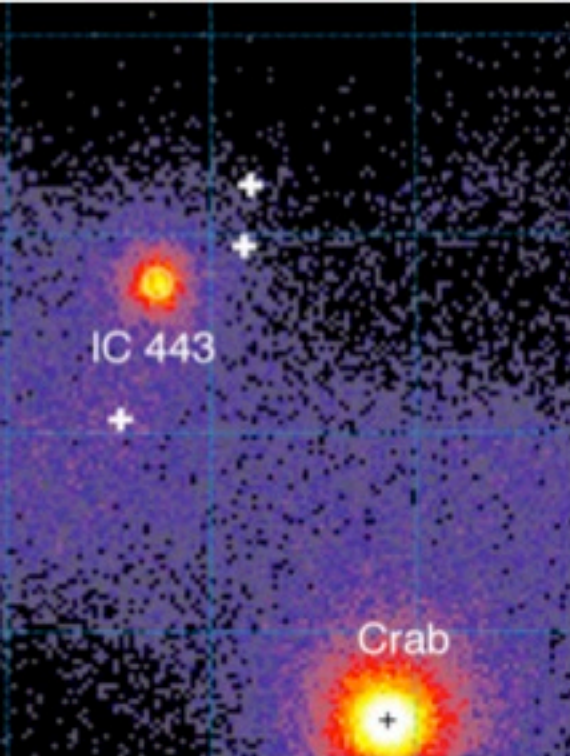
- ▶ **Origin of Galactic Cosmic Rays (GCR):**
  - ▶ What are the accelerators?
  - ▶ What are they accelerating?
  - ▶ How do they propagate in the Galaxy?
  - ▶ Where is the Transition between Galactic & ExtraGalactic CRs?
- ▶ **Origin of ExtraGalactic Cosmic Rays (XGCR):**
  - ▶ What are the accelerators?
  - ▶ What are they accelerating?
  - ▶ How do they propagate to Earth?
  - ▶ At what Energy COSMIC RAY ASTRONOMY begins?
- ▶ **How do Cosmic Rays Affect the Earth, the Solar System, the ISM, the Galaxy, other Galaxies, and the formation of Stars and Galaxies?**

# Open Questions in CR Science

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- ▶ Origin of Galactic Cosmic Rays (GCR):
  - ▶ **What are the accelerators?** (CosmicSIG + GammaSIG)
  - ▶ What are they accelerating?
  - ▶ How do they propagate in the Galaxy?
  - ▶ Where is the Transition between Galactic & ExtraGalactic CRs?
- ▶ Origin of ExtraGalactic Cosmic Rays (XGCR):
  - ▶ What are the accelerators?
  - ▶ What are they accelerating?
  - ▶ How do they propagate to Earth?
  - ▶ At what Energy COSMIC RAY ASTRONOMY begins?
- ▶ How do Cosmic Rays Affect the Earth, the Solar System, the ISM, the Galaxy, other Galaxies, and the formation of Stars and Galaxies?

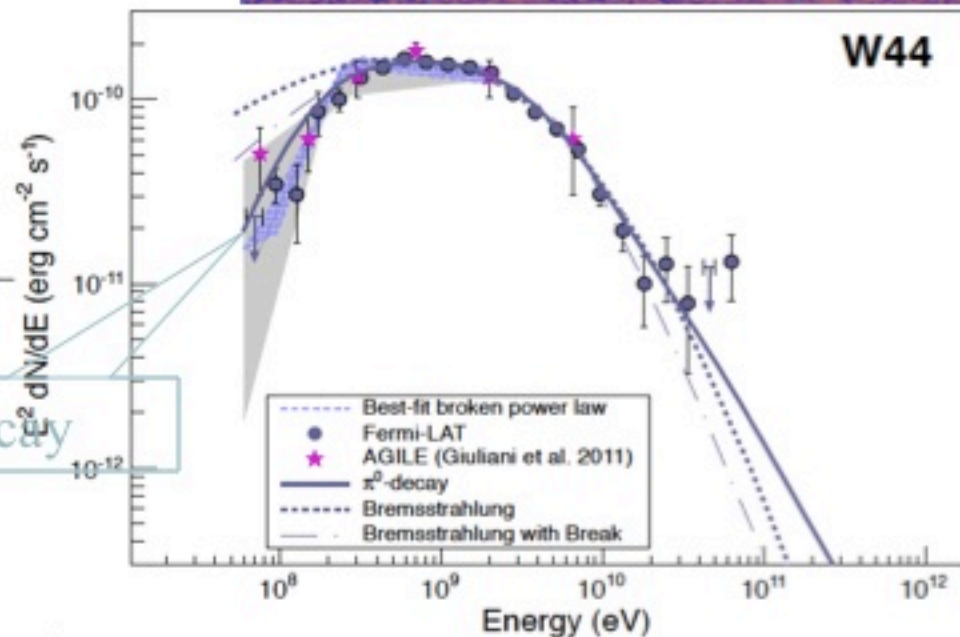
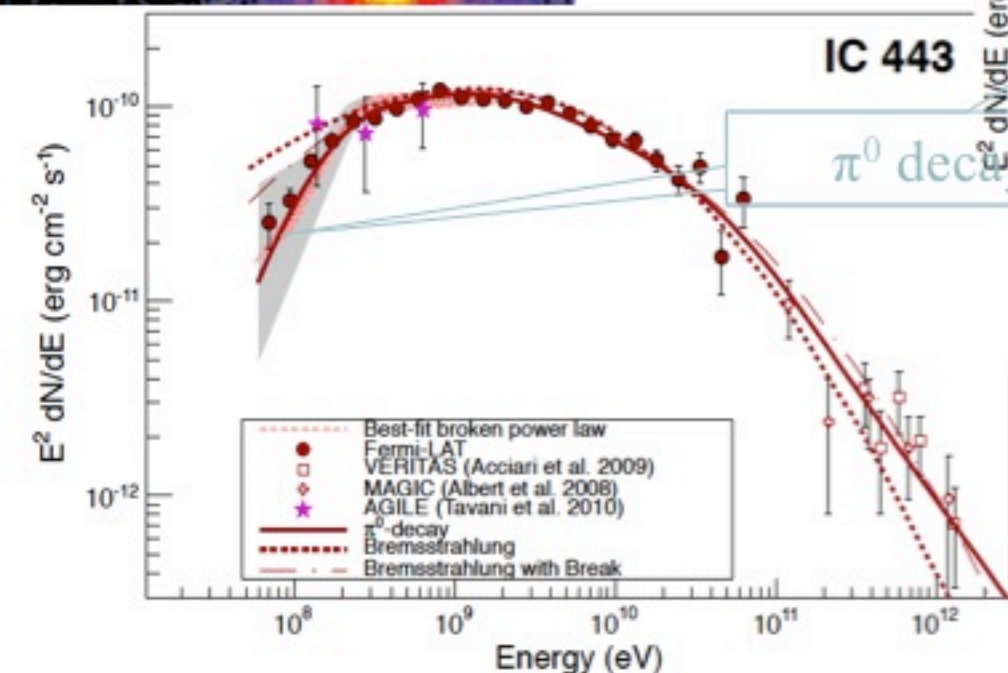
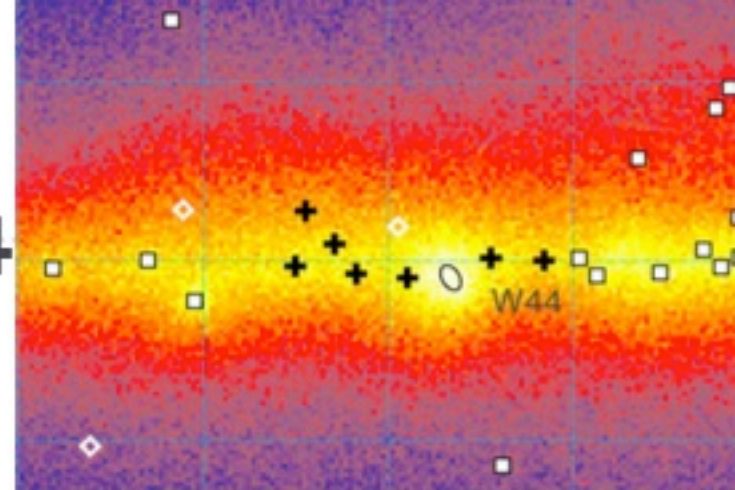




# $\pi^0$ decay!

## IC 443 & W44

### Fermi & AGILE

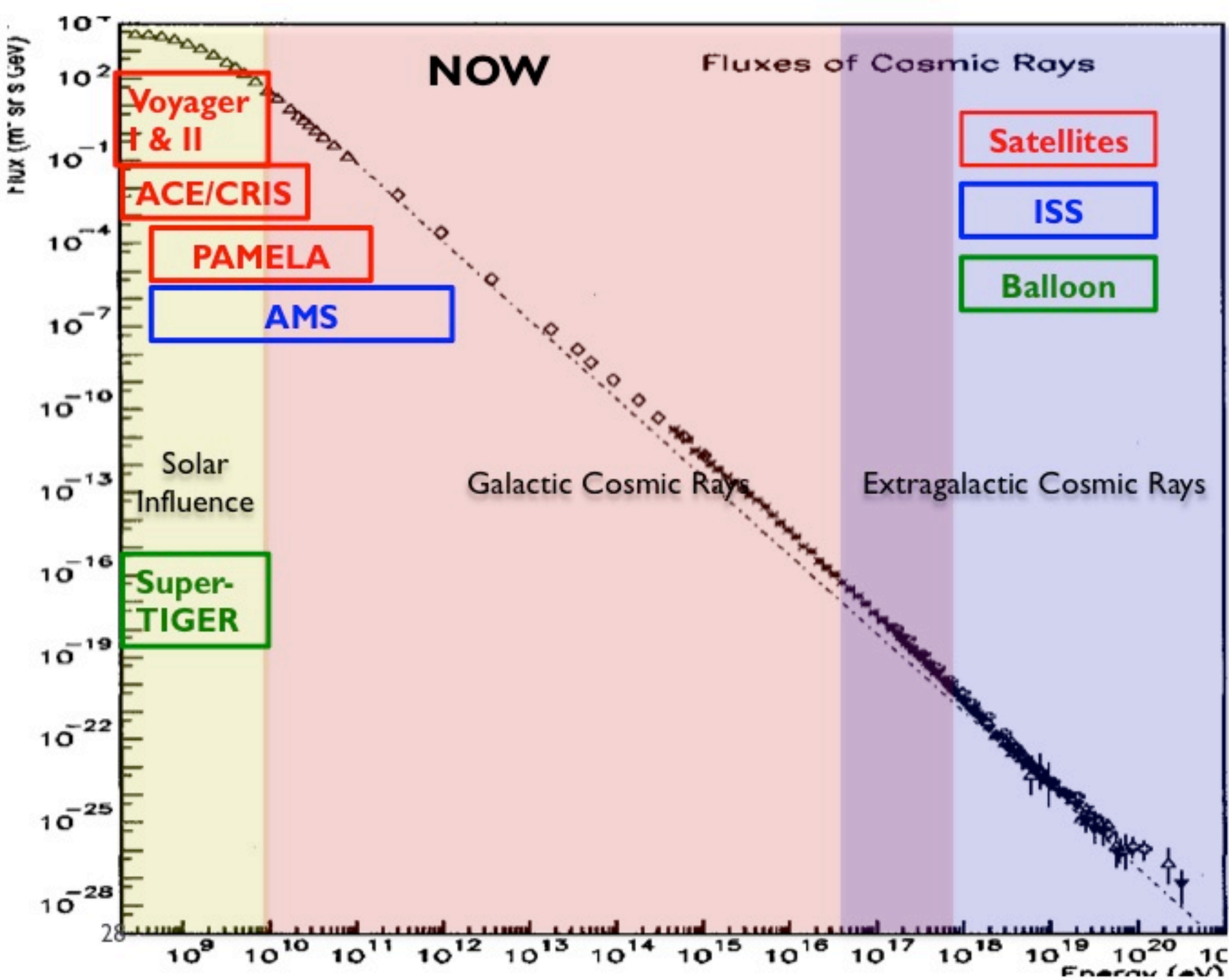


Ackermann et al (Fermi Collab) '13  
arXiv:1302.3307

# Questions Related to CR Science

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- ▶ Origin of PeV neutrinos
- ▶ Indirect Dark Matter Searches
  - ▶ WIMP in the Galactic Halo:  $e^+$ ,  $e^-$ ;  $p$ , anti- $p$ ,  $\gamma$ ,  $\nu$  ...
- ▶ Probe of Particle Interactions above LHC energies
  - ▶ Ultrahigh Energy Cosmic Rays (UHECR)  $E_{\text{cm}} > 100 \text{ TeV}$
  - ▶ Ultrahigh Energy Neutrinos
- ▶ Searches for Exotic Components of Matter:
  - ▶ antinuclei
  - ▶ Magnetic Monopoles
  - ▶ Strangelets
  - ▶ Qballs
  - ▶ Primordial Black Holes







# "Cosmic Ray Observatory on the ISS"



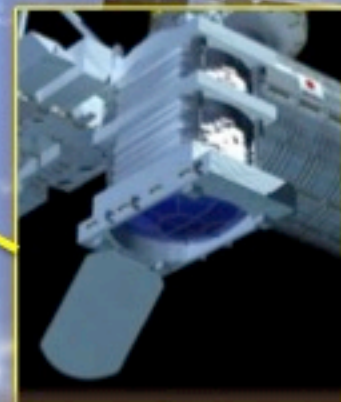
AMS Launch  
May 16, 2011



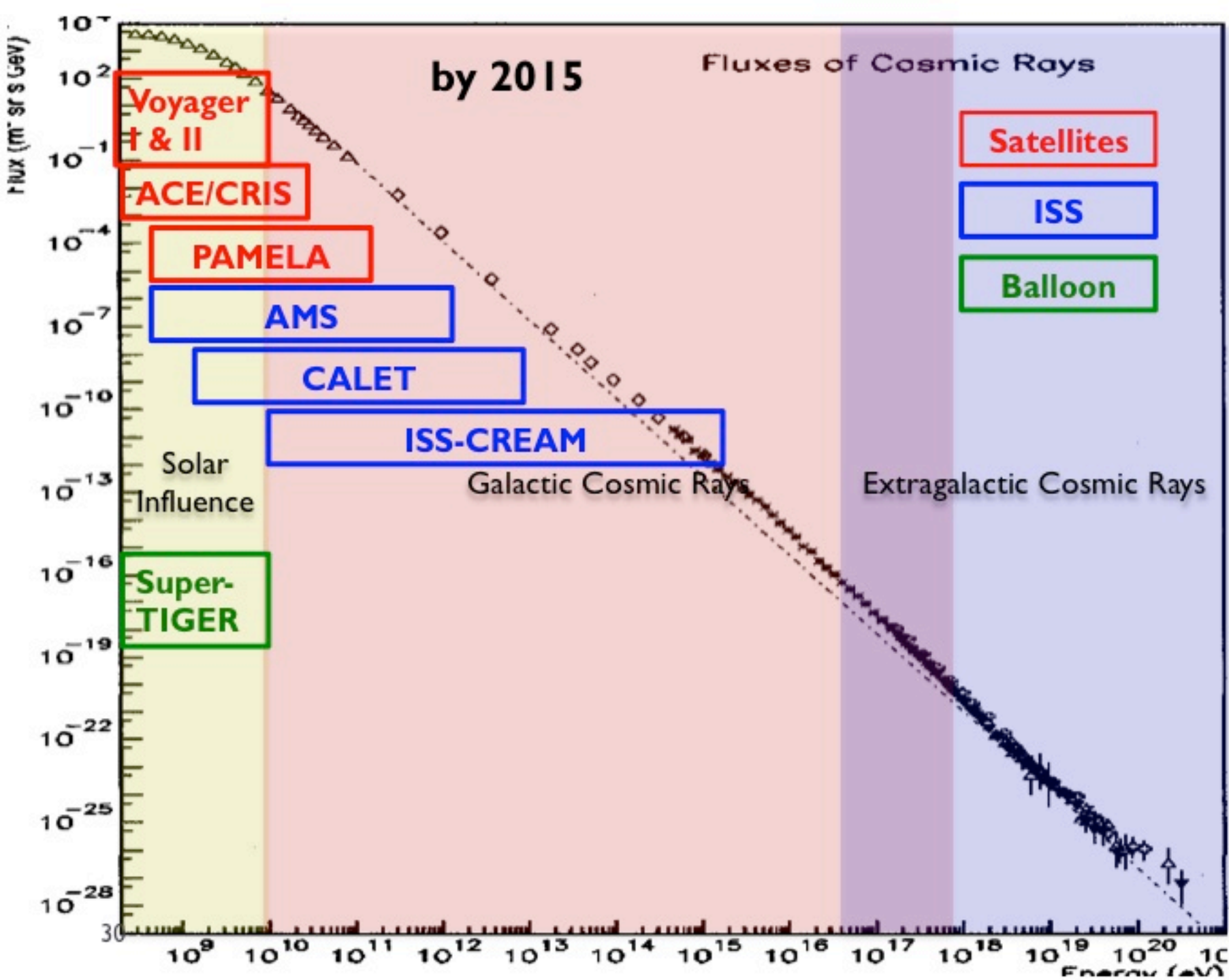
ISS-CREAM  
Sp-X Launch 2014



CALET on JEM  
HTV Launch 2014



JEM-EUSO  
Launch Tentatively  
planned for 2017





# ISS-CREAM update



CosmicSIG  
January 5, 2014

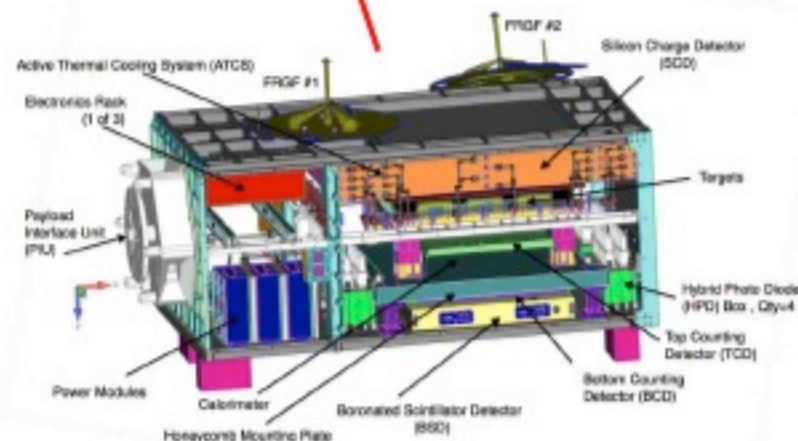
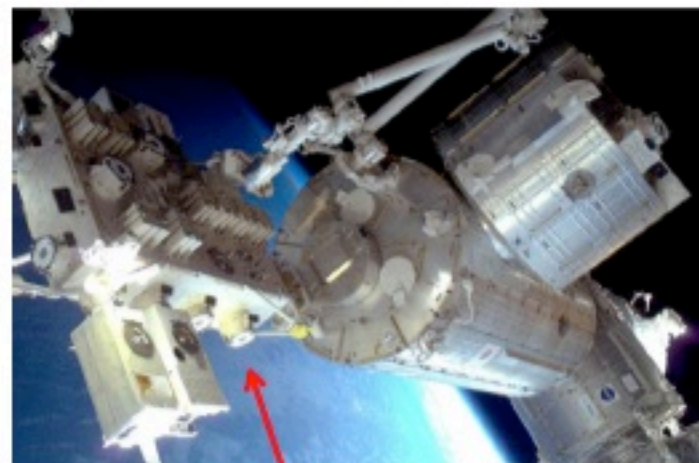
## Cosmic Ray Energetics And Mass for the International Space Station (ISS-CREAM)

### Mission Design

- Launch in Dec. 2014
  - SpaceX-6 (External Cargo)
- ISS Location: JAXA's JEM-EF 2
- Mass
  - Up Mass: Payload- 1342 kg with reserves
  - Down Mass: 0 kg

### Mission Goal

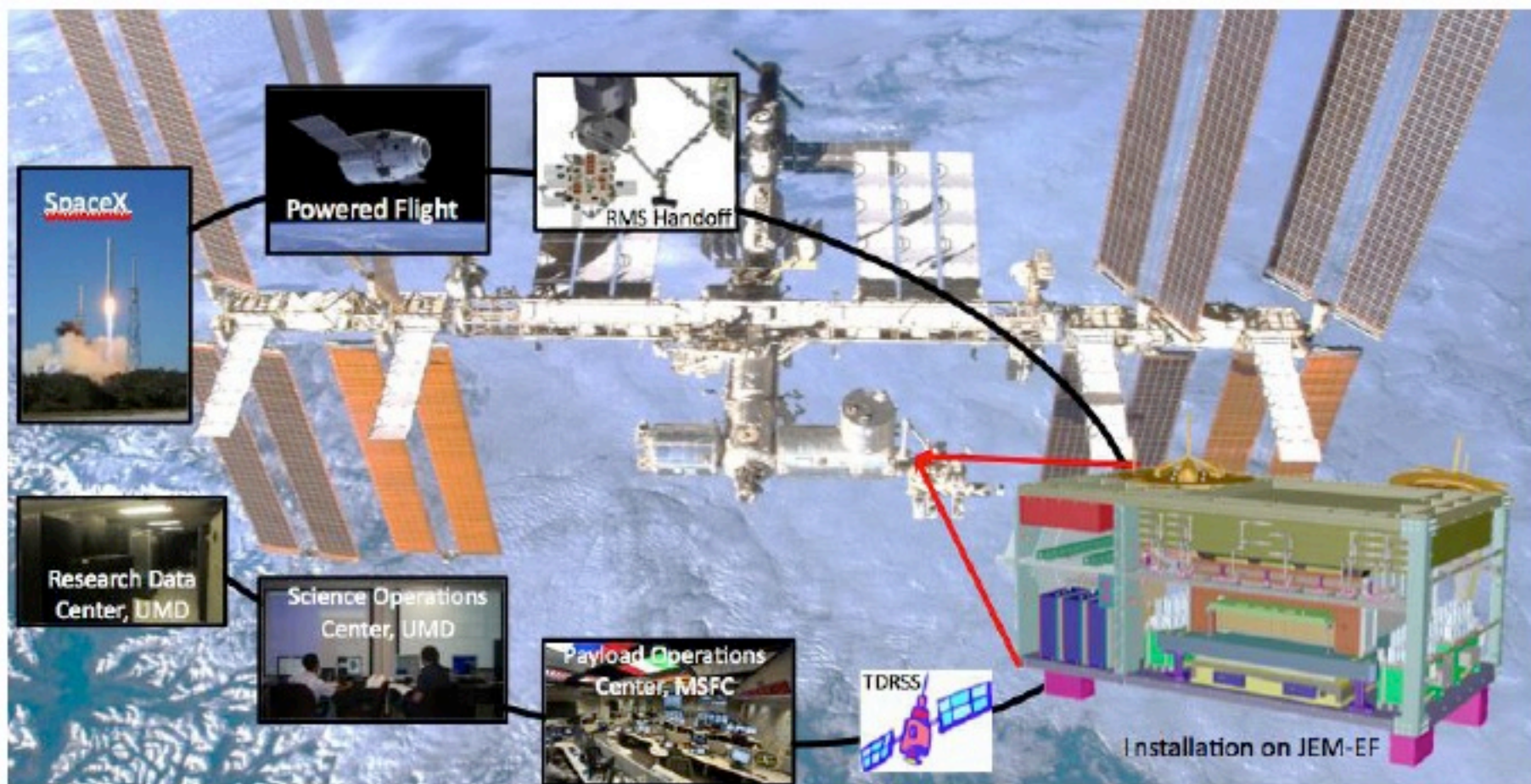
- Extend the energy reach of direct measurements of cosmic rays to the highest energy possible to investigate cosmic ray origins, acceleration and propagation.





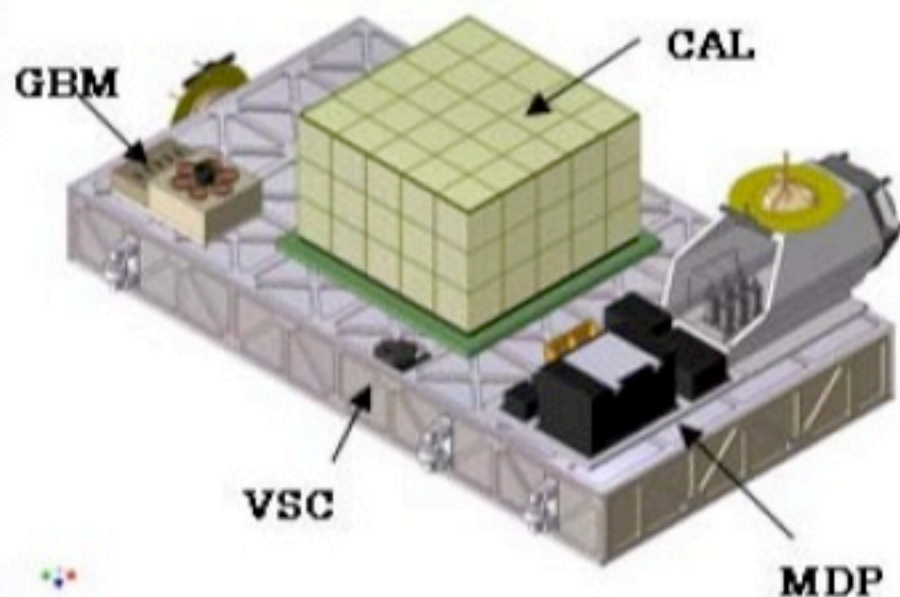
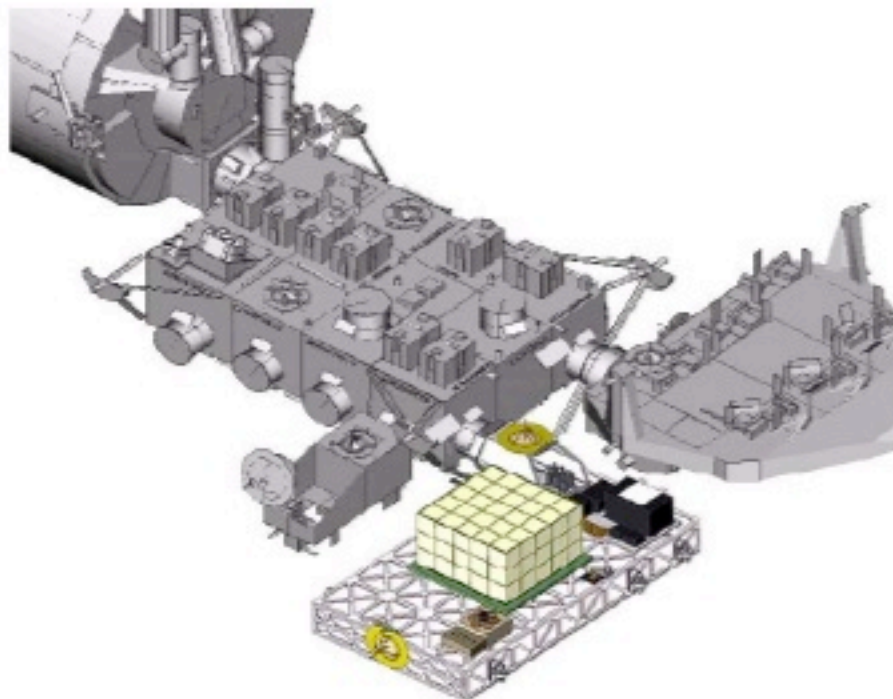


# Mission Phase Overview

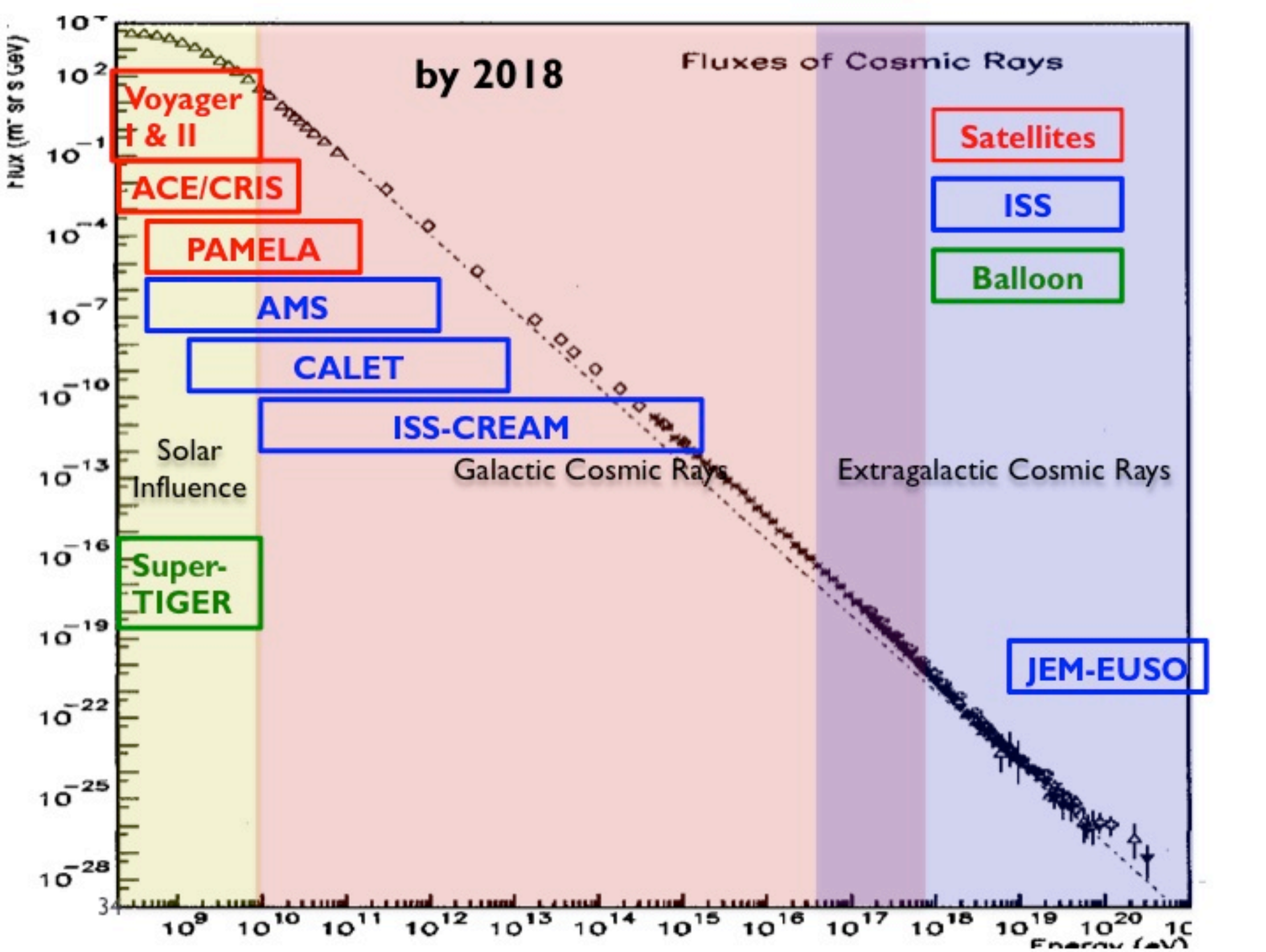


# CALET update

- ▶ Launch planned for 2014 with HTV delivery to ISS









# JEM-EUSO update

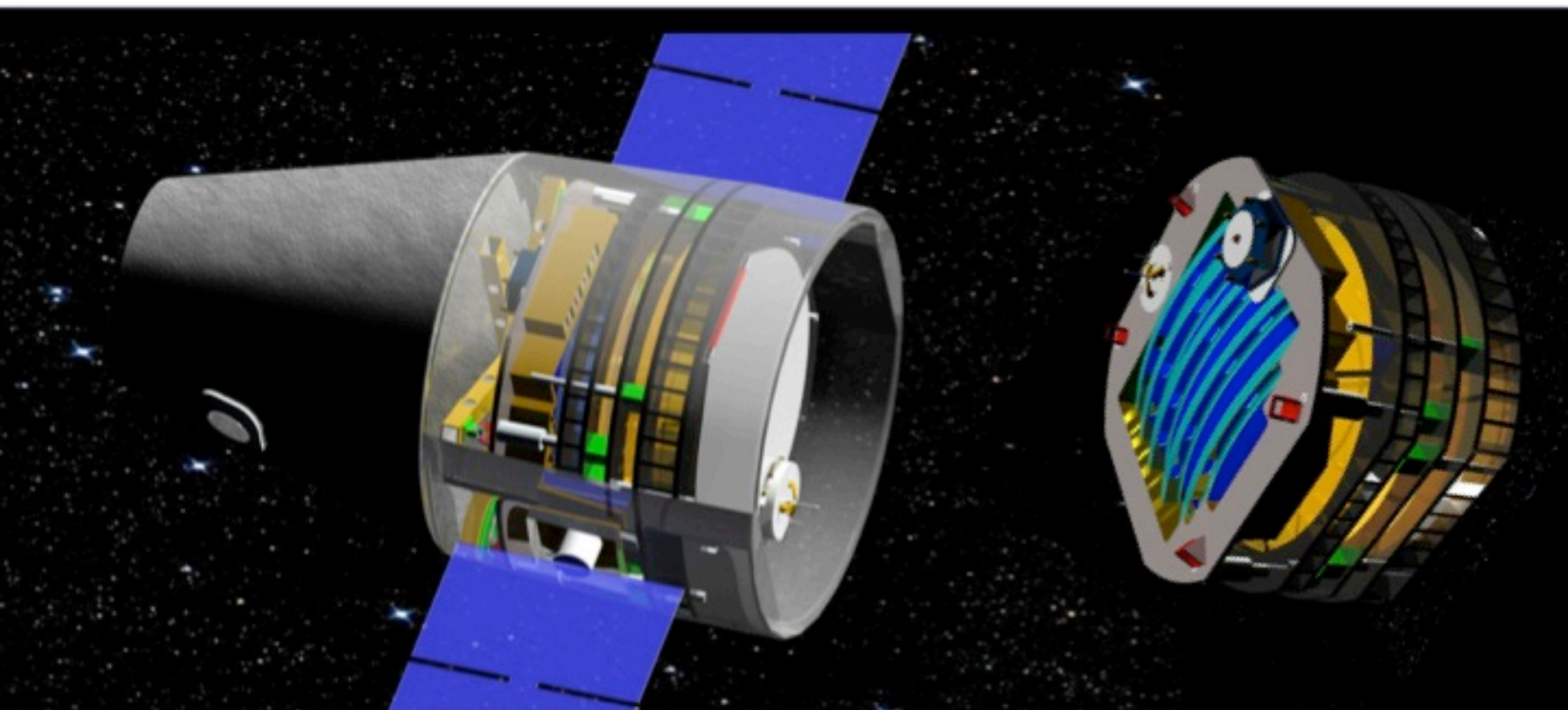
- ▶ Extreme Universe Space Observatory (EUSO)  
in the Japanese Experiment Module (JEM)  
of the International Space Station (ISS)

JEM-EUSO goals (EECR = Extreme Energy Cosmic Rays)

- pioneer the study of EECR from Space
- increase exposure to EECR by 1 order of magnitude
- discover the nearby sources of UHECRs

# JEM-EUSO update

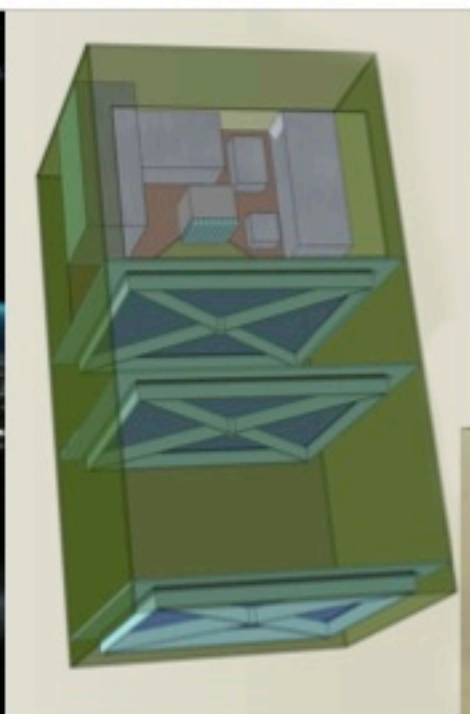
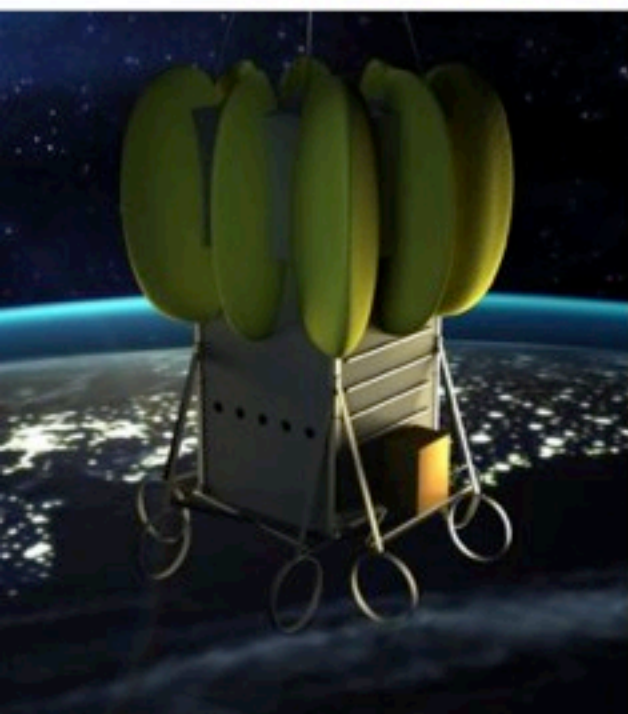
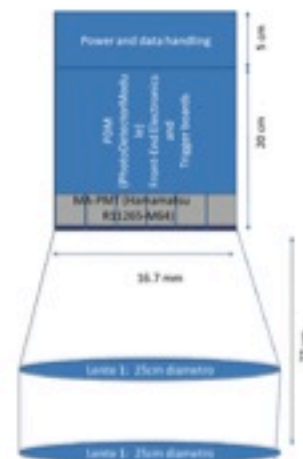
- Redesigned for SpaceX Dragon Delivery





# JEM-EUSO update

- ▶ Redesigned for SpaceX Dragon Delivery
- ▶ Pathfinders:
  - ▶ EUSO-Balloon first launch in 2014
  - ▶ EUSO-TA commissioning Spring 2014
  - ▶ Mini-EUSO launch 2015-16





# Opportunities in Space

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- ▶ In Situ Measurements of Solar System
  - ▶ Voyager I & II
- ▶ Ultra Heavy Nuclei
  - ▶ ACE/CRIS
  - ▶ Super-TIGER
- ▶ Precise Measurements from GeV to TeV
  - ▶ PAMELA
  - ▶ AMS
  - ▶ CALET
- ▶ Galactic Cosmic Rays up to the knee
  - ▶ CREAM, TRACER
  - ▶ ISS-CREAM
- ▶ Extragalactic Cosmic Rays
  - ▶ JEM-EUSO
  - ▶ OWL/PATEL

# Space Opportunities for Cosmic Ray Science



AMS